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L. C. ILSLEY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

FATAL AND NONFATAL ELECTRICAL ACCIDENTS IN COAL MINES[1]

By L. C. Ilsley[2]

INTRODUCTION

Many accidents rightly classifiable as electrically caused are not so classified for the reason that in numerous accidents the part that electricity played in causing the fatality is only suspected. For instance, a workman might receive a shock that would cause him to lose his balance and fall beneath a trip of cars; if no one saw the first part of the accident, the cause undoubtedly would be charged to "haulage."

This paper covers a brief study of fatal and nonfatal electrical accidents. The first usually result from direct contact with the electrical circuit or electrical apparatus; the second more often are the result of arcing or flashing due to handling defective apparatus or making repairs on "live" equipment or circuits. It is hoped that helpful suggestions may be offered for minimizing accidents of these two classes.

Compared with the total number of fatalities in coal mines, electrical fatalities do not rank high, but they do account for approximately 50 deaths annually. By proper precautions this number can be reduced greatly. Moreover, due to rapid mechanization of coal mines, if steps are not taken, both the number and relative percentages of this class of accidents are sure to increase.

About 800 men are injured each year in coal mines from electric arcs and flashes. Many of these flashes do not result in serious accidents, but it is evident that their number could be reduced greatly by proper precautions. The chief aim of this paper is to show the cause of such accidents and suggest means of reducing their number.

WHY ELECTRIC-SHOCK FATALITIES OCCUR

The reason for an electric shock is as natural as water running downhill. It is simply a question of fulfilling Ohm's law, with an electric circuit, a given voltage, and the human body, or a portion of it, offering a resistance path. The voltage "E", according to the law $\frac{E}{R} = I$, causes a certain current "I" to flow through the body or portion of the body making up the resistance "R" of the electric circuit. If the body contact is good, a current sufficient to cause death may flow.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7011."

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To explain in greater detail, it may be considered that the resistance of the human body is such that when a part of the body comes in contact with an electric wire or other live part of an electric system, that part of the body also becomes a conductor of electricity, and an electric current passes through the body to the earth or to another conductor. If the body resistance is great or if the resistance is high due to poor contact, the current flowing may be extremely small and one may feel only a tingling sensation. If the resistance is less, due to less body resistance or better contact, enough current may flow to cause a severe burn. If the resistance is still less, enough current may flow to cause death.

There are two reasons why there are not more fatal electric shocks: First, the skin, especially when dry, offers considerable resistance, and therefore the electric current has much smaller effect than would otherwise be the case. Second, the electrical contact with the human body is often poor. When a metal is in intimate contact with a portion of the human body, more current will flow than if contact is made through clothing or other material. Hence, if the ear of a motorman should accidentally come in direct contact with a trolley wire, the results probably would be fatal; while, on the other hand, the same man might grasp a trolley wire, when he is equipped with a dry pair of gloves, with only a tingling effect.

All voltages should be considered potential shock hazards. High voltages are more dangerous than lower voltages. One can be killed by falling out of an airplane from 1,000 feet or from 500 feet; in the first case the fall would be swifter. Similarly, one can be shocked to death from 220 volts or 110 volts; other things being equal, the severer burns and shock would come from the higher voltage.

Low voltages that are not capable of giving current that would cause a fatal shock may, if contacted, startle one into doing something dangerous, such as stepping into the path of a moving car or falling down a mine shaft.

FATAL-SHOCK ACCIDENTS

Study and analysis have been made of 112 fatal-shock accidents in and about coal mines in the United States to ascertain the chief causes of such accidents. These have occurred over a period of several years and are taken from Bureau of Mines records, chiefly from detailed information submitted by companies that entered the National Safety Competition. The results of this analysis are summarized as follows:

Number of fatal accidents tabulated	112
Number of accidents attributed to trolley wires and trolley-pole accessories	89
Number of accidents attributed to power lines	8
Number of accidents attributed to high-voltage circuits (Note: This includes five accidents where low-voltage circuits (telephone or signal circuits) or low-voltage apparatus were charged from the high-voltage lines.)	8
Number of accidents attributed to handling live low-voltage cables	2
Number of accidents attributed to coming in contact with live machine frames	5

From the foregoing tabulation, it can be seen that nearly 80 percent of the fatal accidents from electric shock were caused by contact with trolley circuits; hence, the trolley circuit may logically be considered the main cause of such accidents. Power lines and high-voltage circuits caused the next highest percentages, followed by live (grounded) machine frames.

Of those fatally injured, 41 were miners, 33 worked on haulage systems, 18 were employed in cutting coal, 2 were electrical workers, and the balance, 18, were divided among a dozen varied occupations about the mine.

NONFATAL ELECTRICAL ACCIDENTS

From statistics in Bureau of Mines files, study and analysis were likewise made of 58 nonfatal accidents caused chiefly by electric flashes.

Of these 58 accidents, 8 were no-lost-time accidents and 50 had a total lost time of 1,211 days, or an average of 24.2 days. The chief causes, in order of frequency, were short circuits, 18; defective cables, 14; defective machine wiring, 13; and contact with trolley wire, including flashing from wheel and nips, 13. Undoubtedly most of the accidents listed in the first three items were caused by flashes either when equipment or wires were short-circuited or when heavy currents were interrupted unexpectedly.

Those injured in these accidents were 17 motormen and helpers, 11 machinemen, 6 electrical workers, 13 miners or laborers, and 11 others.

It is believed that lack of inspection and proper maintenance are the indirect causes of a large proportion of the foregoing nonfatal accidents. Careless or ignorant handling of electrical equipment is undoubtedly among the other causes of such accidents.

STATISTICS FROM PENNSYLVANIA COMPENSATION RATING AND INSPECTION BUREAU, 1926-1930

The following tabulation was abstracted from statistics furnished by the Pennsylvania Compensation Rating and Inspection Bureau for 1926-1930:

Cause of accident	Number of accidents	Days lost
Trolley wires	37	1,471
Machine cables	13	363
Locomotives	62	1,061
Switches	6	99
Light wires	5	76
Car hoists	8	150
Other contacts	11	217
	142	3,437

From the foregoing tabulation, trolley wires are responsible for more days lost time than any other type of electrical contact.

EXAMPLES OF SUCCESSFUL RESUSCITATIONS

The following examples are given in order that the importance of continued resuscitation may be appreciated fully.

1. Patient, age 22, was driving team, came in contact with a charged guy wire, and was knocked unconscious instantly. Nearby workmen rushed to patient and applied artificial respiration. About 3 minutes later the superintendent of the mine appeared and alternated with two others in giving artificial respiration. After 20 minutes the patient began to show signs of life. Artificial respiration continued for another 20 minutes, when patient sat up and breathed about normally. On arriving on the scene, the doctor ordered the patient to bed for the remainder of the day. Patient reported for work on the following day.

2. Patient's (colored coal miner) head came in contact with trolley wire and he was rendered unconscious. He was given artificial respiration by five fellow workers. He recovered and returned to work in 8 days.

3. Patient (colored coal miner) was shocked severely when his hand came in contact with live trolley wire, which he grasped. A loader removed him from the wire and summoned assistance. The patient was placed on blankets, his jaws were pried apart and propped open, and his tongue was pulled out. He was covered with blankets, and the Schaefer method of artificial respiration was administered. Heat was applied to the body, and after about 45 minutes of artificial respiration a physician advised that a very slight pulse beat was detected. At the end of 75 minutes an inhalator arrived, and after 2 hours' respiration the patient was conscious and was then removed to a hospital. Five days later he returned to work.

4. Patient (mine electrician) came in contact with trolley wire while he was riding on a locomotive, and he fell to the ground unconscious with a burn 2-1/2 inches long at the base of the skull. Artificial respiration was given by a fellow worker. After about 15 minutes the patient began to revive. Five days later the patient returned to work.

5. Patient's head came in contact with trolley and he was rendered unconscious. Three fellow workmen administered artificial respiration, and in about 10 minutes the patient was conscious and breathing normally. The patient was then taken to the dispensary and examined by a doctor, who pronounced his respiration good. He was then taken to a hospital, where he died 3 days later.

SUBSTANDARD ELECTRICAL INSTALLATIONS

Examinations of electrical equipment and circuits in about 100 coal mines by engineers of the electrical section of the Bureau of Mines have afforded examples where circuits of machines have not been installed properly when considered from the standpoint of preventing electric shocks. Some of these points are listed below:

Underground Equipment and Circuits

1. Portable drills used without ground wires. 2. Pipelines depended upon for grounding pumps. 3. Keyed metal lamp sockets. 4. Absence of insulating platforms and mats around stationary equipment. 5. Splices in mining machine and other portable cables not properly insulated. 6. Trolley and feeder lines too low or not properly guarded at points where men pass under them. 7. Inadequate or broken bonds. 8. Open knife switches and other unsuitable starting and control equipment for pumps and locomotives. 9. Absence of insulating bushings for wires taken through metal walls of switch cases and motor frames. 10. Space around live equipment inadequate to permit men to work safely around it. 11. Poor negative connection for equipment used on grounded d-c systems. (Return wires placed where they can be stepped on and broken loose.) 12. Fusing of negative as well as positive line to pumps, etc., connected to grounded d-c system. (Negative fuse may open and leave pump charged.) 13. Use of open-link fuses in metal switch boxes, which may result in a grounded box. 14. Dirt and moisture allowed to accumulate. 15. Absence of ground wires on starting equipment. 16. Splices in ground wires, which may cause so high a resistance as to make grounding ineffective. 17. Trolley wires not properly located with respect to rail.

Surface Equipment and Circuits

1. Portable drills without ground wires. 2. Shop and tipple equipment without ground wires. 3. Broken ground wires. 4. Absence of insulating platforms and mats around switchboards, starting and other electrical equipment. 5. Trolley wires in tipples and yards too low or unguarded. 6. Open knife switches, particularly in poorly illuminated places. 7. Absence of insulating bushings for wires taken through metal cases, frames, and conduit

ends. 8. House-type fittings (receptacles, plugs, switches, push-button stations, etc.) unsuited for use around tipples and cleaning plants, where water and chemicals are used freely for dust treatment and cleaning purposes. 9. Wires not properly supported out of contact with vibrating metal to prevent grounding by rubbing through insulation. 10. Wires of one circuit sagging against those of another circuit. 11. Failure to use of maintain devices for detecting grounded circuits. 12. Ungrounded metal lamp sockets in tipples and other places where men may stand on metal or ground in replacing bulbs. 13. Makeshift signaling devices in tipples with bare metal contact parts. 14. Failure to prevent access to high-voltage equipment in substations by unauthorized persons. 15. Fuses too large or overload relays set too high to give proper protection to equipment.

HOW ELECTRIC-SHOCK ACCIDENTS CAN BE ELIMINATED

One of the surest means of reducing the number of electric-shock accidents is to purchase well-designed equipment and install it properly. This generally means paying a higher price for adequate insulation of parts, substantial construction of housings, and ample electrical protection of the circuits. In the end the cheapest apparatus often proves to be the most expensive, economically, and much more expensive when safety is considered. Properly installed equipment requires consideration of the following: Protection from mine dust, water, and roof falls, also provision of ample room for its safe operation.

The men who operate the equipment should be selected with care and thoroughly instructed in their duties. Many accidents are caused by inexperienced men. The electrician who keeps the apparatus in repair should be competent to handle the intricate tasks inherent in present electrical equipment, and he should not be stinted in supplies or help to make needed repairs. The inspector who checks the safety of electrical equipment should understand electrical machinery thoroughly, and his recommendations should go to those in authority in order that needed action may be taken.

Unguarded trolley and power circuits are the most hazardous features of underground electrical installations. Trolley circuits, being bare, are the chief cause of electric shock in underground mine working. If trolley circuits were guarded throughout their length, there would be a decided improvement in the accident rate. All such circuits should be guarded where men must pass under them or where the road in which the trolley wire is installed is used as a travelway for men or animals. Also, where the roadway does not permit the trolley wire to be installed at a safe height, the wire should be guarded. While the guarding of feed wire is not as important from a hazard exposure standpoint, there are places like cross-overs where safety considerations make such guarding necessary.

The importance of maintaining electrical apparatus and circuits in good condition cannot be emphasized too much. Many a man has been shocked from coming in contact with a sagging wire. Defective machines have caused the death of their operators. In many cases, these defects if repaired promptly would not have been the contributing causes of these accidents. Neat and orderly installations insure more carefulness on the part of all who have anything to do with operation of equipment and circuits and should be a part of a safety program.

Improvement in underground illumination undoubtedly will reduce electrical accidents. Rock dusting lightens the walls of roadways and helps to show the presence of electrical wiring. Lights along roadways are also encouraged for the same reason. Ample light should be provided in repair shops and repair pits.

Finally, false economy in ordering supplies should be avoided. If it is necessary to splice cables temporarily, the lives of machine operators should not be endangered by refusing to furnish the necessary tape to make a safe joint. One fatal accident may cause a $10,000 compensation cost. The cost of a few rolls of tape or other needed supplies is not to be compared with such an outlay. Likewise, foremen and superintendents should give the electricians and machinists sufficient help properly to maintain electrical equipment and circuits in a safe condition.